

Section 974

GUIDELINES FOR PORTLAND CEMENT CONCRETE MIX DESIGN**974.01 Objectives**

The objective in designing concrete mixtures is to determine the most economical and practical combination of available materials to produce a concrete that will satisfy the performance requirements under particular conditions of use. To fulfill this objective, a properly proportioned concrete mix will possess these qualities:

- a. Acceptable workability of freshly mixed concrete
- b. Durability, strength, and uniform appearance of hardened concrete
- c. Economy

Understanding the basic principles of mix design is more important than the actual calculations. Only when the properties are understood can the required quality be maintained by controlling the methods of concrete production throughout the job. Mix design is only the means to the production of concrete with all the desired properties from start to completion.

Workability is the property that determines the ease with which freshly mixed concrete can be placed, consolidated, and finished without harmful segregation. Workability is difficult to measure, but it can be readily judged by experienced batch operators, concrete finishers, and technicians. Thus, proportioning a concrete mixture for acceptable workability is an art as well as a science.

If acceptable materials are used, the properties of hardened concrete such as durability, freeze-thaw resistance, water-tightness, wear resistance, resistance to abrasion, and strength are dependent upon the selection of a cement paste; that is, one with a sufficiently low ratio of water to cement plus an adequate system of entrained air. These properties, and thus the desired concrete quality, can only be fully achieved through proper placement and finishing followed by prompt and effective curing.

974.02 Quality Tests

Sand and aggregate intended for use by the contractor or supplier for the project must meet the gradation and quality tests as outlined in section 03055 Part 2 of the Standard Specifications CSI Format and shall be tested and approved for acceptance prior to use.

974.03 Materials for Mix Design

The mix design shall be made using aggregates from the same aggregate source as intended for use on the project. The aggregate shall meet the gradation specification and tolerance as specified in section 03055 Part 2. The cement and admixtures used in the mix design shall be freshly manufactured and of the same type and from the same source and/or stockpiles as the contractor will be using on the project. Mixing water should be potable.

974.04 Number of Trial Batches

In order to cover construction variables and most eventualities that might occur, it is suggested that the following six (6) separate mix designs be made as a minimum:

1) Min. specified	35
2) Min. specified	40
3) Min. specified + 46 lb	35
4) Min. specified + 46 lb	40
5) Min. specified + 92 lb	35
6) Min. specified + 92 lb	40

For each of the above designs and based upon statistical data from past concrete projects, the following test tolerances are suggested:

Slump = 2 inches \pm 0.5 inches Class AA(AE)
3 inches \pm 0.5 inches Other classes

Air Content = 6.0% \pm ½ % PCC pavement
6.0% \pm ½ % AA(AE)
5.0% \pm ½ % A(AE)
4.5% \pm ½ % B(AE) and C(AE)

The maximum water-cement ratio shall not be exceeded. When the trial batch is being made, a region materials lab representative should be present to verify the batch procedures and materials used in the mix.

974.05 Batching Procedure

974.05.01 Apparatus

The apparatus necessary to conduct trial batches should consist of the following:

1. Concrete mixer -
 - a. Revolving drum, tilting mixer, motor driven, of 22 gallon minimum capacity, and a one square yard pan for receiving discharge from the mixer.
 - b. Ready-mix truck mixer that meets requirements of UDOT Quality Management Plan for Ready Mix Concrete, and a wheel barrow for receiving discharge from the truck mixer.
2. Weighing scale - 100 lb capacity graduated to 0.10 lbs
3. Balance - 2600 g capacity graduated to 0.1 g.
4. Container for weighing aggregates and cement.
5. Small tools consisting of square mouth shovel, trowels, brush, and rulers or measuring tape.

6. Graduated cylinders of 1 quart and 3.5 ounce capacities for measuring air-entraining concentrate and dilute solutions.
7. Slump cone and rod.
8. Air meter. (When air-entrained concrete is batched)
9. Concrete cylinder cans. Beam molds for PCC pavement concrete.
10. Hand vibrator. (Where slump requires)

974.05.02 Materials

1. Cement - type of cement to be used on the project, recently manufactured.
2. Coarse and fine aggregates from the source to be used on the project. There should be sufficient amount of material for all trial batches and required physical tests.
3. Air-entraining admixtures and/or water-reducing admixtures, and other admixtures or pozzolan (when approved) from the same source and batch, if possible, to be used on the project.
4. Water (if practicable) from the source to be used on the project.

974.06 Design of Concrete Mixture

There are several methods in designing a concrete mixture. Weight proportioning methods are fairly simple and quick for estimating mix proportions by an assumed or known weight of the concrete per unit volume. A more accurate estimate involves use of the specific gravity value for all the ingredients to calculate the absolute volume each will occupy in a unit volume of concrete. Any one of the methods of proportioning concrete ingredients will produce approximately the same final mix.

974.06.01 Procedures

1. Measurements - The exact quantities of cement and aggregate are determined by weight; the water may be weighed or be measured in a graduated container.
2. Recording - A data sheet showing all the batch weights actually used should be filled out and kept for future reference.
3. Pre-wetting Aggregate - To simplify calculations and eliminate sources of error caused by variations in aggregate moisture content, the aggregates should be

prewetted, dried to saturated, surface-dry condition, and placed in covered containers to keep them in this condition until used.

4. Admixtures - Before starting trial batches, check all admixtures for compatibility.

In order to facilitate accurate measurement and even dispersal of the mixture, a dilute solution is used. If two or more admixtures are used, such as an air-entraining and a water-reducing admixture, separate dilute solutions should be made. Each solution should be added to separate portions of the mixing water before being added to the batch.

5. Laboratory Concrete Mixing for Trial Batches

- a) Buttering - Prior to mixing the test batch, the mixer shall be 'buttered' by mixing a partial batch (about one-half the normal size) having approximately the same composition as the trial batch.
The buttering batch is discharged and wasted, leaving a normal coating of mortar on the inside of the mixer drum so that no selective removal of mortar from the test batch will occur. The pan into which the test batch is to be discharged shall also be buttered and then kept damp until the batch is discharged into it.

- b) Trial Batches - When charging the mixer, place approximately one-third of the water mixed with a water reducing agent (if used) in the mixer. Start the mixer. Place all of the coarse aggregate (gravel) in the mixer then add all of the fine aggregate (sand) on the gravel. The cement and pozzolan (if required) is placed on top of the aggregate. Another one-third of the water mixed with air-entrainment agent is added to the mix. Then add a sufficient amount of water as mixing progresses to obtain the desired consistency (slump). Keep an accurate record of all water used in the batch.

Mix the concrete for two minutes using an accurate, visible timer. Turn off the mixer and rest the mix for two minutes. During this period, cover opening of mixer with wet burlap to prevent moisture loss. At the end of rest period, turn on mixer and mix for the last two minutes. At the end of the mixing period, the concrete is dumped from the mixer into a water-tight, buttered, moistened, and non-absorbing pan of such size and shape that the concrete can be turned over with a square mouth shovel to eliminate segregation.

6. Tests of Plastic Concrete - Tests shall be performed on the plastic concrete: slump, air, and unit weights. All tests shall be made in accordance with that specified in section 03055 of the 1999 Metric Standard Specifications CSI Format.

7. Hardened Concrete - Two compressive strength tests shall be made for each batch. Three concrete cylinders shall be broken at 28 days to determine the attained compressive strength, and one beam (PCC pavement) shall undergo a flexural beam test to determine the modulus of rupture.
8. Report - A complete report showing all trial batch data (such as weights, amount of water, admixtures used, etc.) including air, slump, and compressive strength and flexure tests (when appropriate) shall be submitted to the project engineer for review and approval prior to starting the placing operations.

If the trial batch mixes with the two sand percentages fail to meet the required design strength with the gradation selected, then additional mix designs shall be made using a different gradation, i.e. if a 2 inch maximum gravel was used initially, then change to a 3/4 inch or 1 inch maximum size and repeat the mix design.